Mechanical application to area reduction

Summary
In patterned minefields (ones in which mines are laid in rows or clusters), machines are used to identify the presence of mines (i.e. the start of a row). In non-patterned mined areas, machines are used to identify areas containing mines. The potential for machines to reduce the amount of land considered contaminated with mines and UXO is enormous. Indeed, productivity results in the two case studies in this chapter show that investment in an area reduction machine results in a high return when compared to the other clearance methods used (MDD and manual). Eliminating non-hazardous areas where no evidence of a threat is found through systematic mechanical area reduction has clear advantages. It allows mine clearance resources to be deployed to where real threats are located, eliminating huge suspect areas that do not contain mines. A more efficient approach to humanitarian demining would therefore be, where topography allows, to confirm the presence of mines through appropriate application of mechanical technology and then to reassess which areas actually need clearance.

Introduction

Background
In Chapter 2, we looked at the potential for mechanical systems to be employed for risk reduction. In this chapter, we look at the allied topic of area reduction as part of the technical survey process. Area reduction is defined by the IMAS as “the process through which the initial area indicated as contaminated is reduced to a smaller area”. Generally, the reduction is conducted on the basis of collecting more reliable information on the extent of the hazardous area.

Area reduction using machines is a relatively new concept with no formal or fully understood techniques or procedures yet established. Demining organisations find that the majority of land cleared does not actually contain mines. There is a strong need to identify actual contaminated areas quickly and accurately.

Minefields in general can be placed in two distinctive categories: patterned and non-patterned minefields. A patterned minefield is one in which mines are laid in
rows or clusters: such minefields are also known as “defensive” minefields and are used to protect valuable resources and military positions. When one mine is detonated or otherwise located, it can indicate the location of the remaining mines. Thus, information gained about the presence of one or more mines can be used to determine the presence of other mines in the area. Usually, a high number of mines are laid in a patterned minefield.

A non-patterned minefield, however, can be offensive or defensive. Often these types of minefields (or mined areas) are a result of a low intensity conflict over a long period of time, where mines have been used as individual weapons. When one mine has been located in a non-patterned minefield its location cannot be used to determine the location of other mines in the area, although it is not unusual to find high concentrations of mines that are non-patterned.

Terms of reference

The sub-studies that form the basis of this chapter aimed to assess techniques used in area reduction operations by machine and to establish a framework for appropriate mechanical application to a minefield.

The chapter bases its conclusions on the use of machines in two minefield scenarios. The first case study is based on area reduction in Abkhazia by The HALO Trust in a patterned minefield scenario.

The second case study is based on area reduction techniques used in Thailand by the Thai Mine Action Centre (TMAC) in a non-patterned minefield scenario. The procedures used in the TMAC case study are defined as both risk reduction and area reduction, although the case study only focuses on area reduction.

Case study 1: Area reduction of patterned minefields in Abkhazia

Introduction

This case study is based on area reduction of patterned minefields in Abkhazia between 1999 and 2000 (area reduction has been undertaken there since 1998). It covers clearance operations along the banks of the Gumista river, which lies within the city limits of Sukhumi City.

Mine contamination in Abkhazia

There are basically three different minefield scenarios in Abkhazia. First, Georgian forces laid belts of mines at intervals along a seven-kilometre stretch of the southern banks of the Gumista river, when they occupied Sukhumi. The Georgians carefully mapped their minefields, laying dense mine belts of both PMN and PMN2 anti-personnel mines, no more than one metre apart, as well as the TM series of anti-tank mines (TM46, TM57) in specific places.

Second, Ochamchire province in central Abkhazia was the scene of the surprise attacks by the Abkhazians and as such no real frontline was established. The minefields in this area therefore were not mapped, are not well known and contain a non-patterned
mix of Soviet-era anti-personnel and anti-tank mines and locally produced improvised mines and explosive devices.

Third, the Abkhazians laid minefields along its then newly established border with Georgia, notably along the northern banks of the Inguri river. The mines were generally laid in rows or patterns but the accuracy of these minefields is not as good as those laid along the Gumista river.

**Fig. 1. Abkhazia, Republic of Georgia**

**Minefield conditions**

Initially, mine clearance in Abkhazia was conducted along both the Gumista and Inguri rivers. The metal contamination in these areas was extremely high, particularly along the Gumista, as it was both a light industrial area and a frontline where frequent exchanges of small arms ammunition, light mortars and rocket-propelled grenades took place. Both rivers, however, are equally affected by the granite-like boulders (many ferrous) which dominate the sub-soil, so much so that the ground is best described as granite boulder with a thin layer of topsoil.

These two dominating factors — high metal contamination and rocky ground — make manual mine clearance techniques extremely slow. In fact, daily manual clearance rates along the Gumista river rarely exceeded five metres per lane and many lanes were manually excavated. In addition, mine clearance generally takes place during only ten months of the year as snow and frozen ground during the height of the winter season make many clearance options impractical.

Terrain that was being demined along the Gumista river is generally flat, even including an old football field that was mined. There are areas of overgrown grass, shrubs and blackberry bushes.

**Area reduction in Abkhazia**

**The rationale**

IMAS defines two types of surveys: the general mine action assessment and the technical survey. The
The purpose of the first is to assess the scale and impact of the landmine problem on a country and individual communities and is generally based on verbal and documented information. The technical survey is also based, among other things, on verbal and documented information but with the aim of collecting sufficient information to enable the clearance requirement to be more accurately defined by doing something physically to the area.

The process through which the land identified in the general mine action assessment — often referred to as a Suspected Hazardous Area (SHA) — is subsequently reduced to a smaller area is known as area reduction. Area reduction is an integral part of the technical survey process.

The use of machines to initiate some of the mines provides an organisation with a greater degree of information about where the mines exactly are and what areas need to be cancelled out.

At the time of initiating their operations, HALO was given the maps of the Georgian minefields along the Gumista river, which provided details of the location of mine belts in relation to each other and other key reference points, as well as the type and number of mines laid. But HALO did not know how accurate the information was, so it had to test it.

**The clearance options**

HALO conducted a risk assessment focusing on how they could use the information they had. Three options were apparent. The first was to deploy manual survey lanes to locate the mine belts and then subsequently clear the belts. This would mean the mine belt environs would receive limited verification. The risk of randomly laid mines was unknown and therefore needed investigation. The second option was to deploy a machine that would both identify the dense mine belts and provide a method of proving the ground in and around the mine belts (testing the information). The third was to simply manually clear the entire area initially identified (also thereby testing the information).

**The decision**

HALO chose the second option. The risk assessment recognised that the belts of mines represented the true minefield, but the environs needed a degree of verification. Manual clearance rates were extremely slow and a demining lane would not provide the coverage needed to make contact with the front row of mines in the belts. Mines were laid one to two metres apart and as the typical demining lane is only one metre across, it may clear land between mines and not locate the rows.

HALO chose to conduct area reduction operations (to indicate mine belts and verify areas) with a Pearson Engineering Area Reduction Roller mounted on the front of an armoured Belarus 1507 Tractor or Volvo 4400 front-end loader. The roller is made up of heavy-segmented discs, each five centimetres wide. The discs float on a central axle and thus are able to contour the ground surface extending an even down-force of about 50 kilograms.
Area reduction procedure

The following four factors contributed to the decision to use the Pearson:

1. Even though the Pearson segmented roller is best used on reasonably flat ground or over features easily negotiated by the prime mover, it has a limited ability to overcome surface undulations.

2. In areas that have become overgrown a vegetation cutting attachment is used to reduce the vegetation back to ground level. If the vegetation were merely pushed over, there would be a buffering effect that could lead to some mines not detonating.

3. Area reduction does not take place in areas suspected of containing anti-tank mines. The primary threat in this case was limited to PMN and PMN-2 anti-personnel mines. HALO has found that the roller is at least 90 per cent effective against both these types of anti-personnel mine. The mines must, however, be in working order (correct depth and position so as to be initiated).

4. Moisture in the soil appears to influence the effectiveness of the roller. If the ground is too soft, a concern is that mines could be pushed further in the ground and, as a result, will not detonate. Although the legitimacy of this concern has not been confirmed in trials, the perception influences the areas in which the roller has been used.

Method

The HALO Trust method of reducing areas is divided into three parts. First, the dimensions of the mine belts and the start-line for the manual clearance need to be established. Second, areas between the start-line (boundary of suspect area) and the newly established manual clearance start-line need to be verified to be confident that no mines are present. Third, after clearance of the mine rows are completed by manual teams, to a point 10 metres beyond the final row, rolling recommences to verify the remaining ground between the end of the manual clearance and the far end of the minefield.

The tractor/roller drives forward from the established start-line towards the suspected belt of mines. On detonating a mine, the roller reverses for 10 metres and
the operator then lays a marker. It then moves further back to the start-line, then across about 25 metres (less if belts are not linear) and drives again until a mine is detonated. The operator then lays another marker and this continues until the roller has identified the entire mine belt front, plus indicating side dimensions.

The markers then form the starting point for the subsequent manual demining lanes that clear through and 10 metres past the mine belt. The area between the markers and initial start-line is then rolled four times in four different and opposing directions (Fig. 1). Provided there are no mine detonations, this area is cancelled out and receives no further clearance. If, however, a detonation has occurred the area concerned is then deemed to be part of the minefield and subsequently cleared.

**Fig. 6. Phase one and two of the area reduction operation**

**Fig. 7. Use of the roller on the banks of the Gumista river**

**Method effectiveness**

How effective was the mechanical area reduction option?

**Gumista river**

Figure 7 illustrates the use of the roller on one task on the banks of the Gumista river. The threat was from PMN-2 and PMN anti-personnel mines only and no random mines were actually found in the areas reduced by the roller. On this particular task, 49,000 square metres were cleared manually and 95,000 square metres of land were cancelled out.
The project results were as follows:

<table>
<thead>
<tr>
<th>Project cost increase (12 month period)</th>
<th>Project productivity increase (12 month period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>39 per cent</td>
<td>323 per cent</td>
</tr>
</tbody>
</table>

These good results are a combination of low costs and high productivity. The mechanical area reduction costs were minimised by armouring a heavy tractor which could be purchased and maintained in the region. High productivity was achieved by the machine as the ground was open and flat, especially along the banks of the Gumi sta river.

**Case study 2: Area reduction of non-patterned minefields in Thailand**

**Mine and UXO contamination in Thailand**

Landmines have been used in Thailand over the past 40 years by conventional and guerrilla armies on all four of Thailand’s borders. Understanding the need to quantify the mine problem, TMAC commissioned a landmine impact survey to determine the scope and impact of the mine problem in Thailand. The survey, which was completed in April 2001, identified a total of 933 contaminated areas covering an estimated landmass of 2,560 square kilometres. This was an area more than three times greater than that previously estimated by the Thai army.

Twenty-seven provinces on Thailand’s borders are affected by landmines and UXO, impacting on some 530 communities. These are mostly poor rural villages surviving on agriculture and foraging amid contaminated border areas. More than 500,000 Thai people’s daily lives are directly affected by landmines and UXO.

**The challenges to demining**

Unfortunately, it is not known how many mines were laid or where they were laid. Only information on general locations or approximate boundaries of contaminated areas is available. Further, since survey data was obtained from stand-off field observation without circumnavigation of suspected areas, spatial dimensions and densities of mine contamination are also not recorded. Therefore, given that large areas of suspected hazardous land endanger Thai citizens and deny productive use of land, area reduction is the primary focus of risk reduction efforts.

The difficulties inherent in manual area reduction, already relatively slow by its nature, are compounded by Thailand’s terrain and environment along the border areas. Typically, all four border areas are primarily rough tropical terrain with seasonal weather extremes that complicate clearance efforts. Thick tree-canopy jungle, mountainous areas, laterite soils and tropical monsoons with their associated diseases, all contribute to the difficult challenges facing both deminers in the field and TMAC planners.

All categories of anti-personnel mines, anti-tank mines and booby-traps are present in Thailand. Particularly noteworthy are the low-metal-content mines
A Study of Mechanical Application in Demining

Figure 8.

Figure 9. Nong Ya Khao village
which are difficult to detect with currently available metal detectors. In addition, as is typical of former battlefields, many items of UXO are regularly found during mine clearance operations — the UXO-to-mine ratio averages ten to one in Thailand.

Significantly, large portions of the border areas were under repeated artillery and mortar fire for some 20 years, contributing millions of pieces of metal fragmentation (shrapnel) in dense concentrations, further complicating clearance efforts. The lethal cocktail of low-metal-content landmines mixed with UXO is concealed in jungle conditions and buried in high ferrous content soil (laterite). Laterite masks or limits current metal detection technology’s capability to locate these hazards.

Each report of a “hit” by either mine detection dog or mine detector must of course be investigated; in some areas, deminers have been getting up to 4-5 “hits” per square metre and each hit requires a slow, painstaking effort to determine the nature and lethality of the item that has caused it (almost all hits are false).

All of these conditions are, individually, difficult for demining; in combination, they make the job even more difficult and resource intensive. Thai deminers work to destroy mines and UXO all year round, in spite of monsoon conditions during nearly half the year and high temperatures almost the whole year. The aim of this effort is to provide land that meets the user requirements, primarily farmers.

In the face of these difficult conditions, TMAC took steps to introduce fully integrated mechanical, MDD and manual demining methods into its operations. The development of “Mined Area and Risk Reduction of Non-Patterned Mined Areas” operations using available technology is TMAC’s operational strategy to address the huge mined areas on its borders. It is important to note that these integrated methods are still under development and there is a need to further improve area reduction methodologies and determine residual risks.

We will now look at the case of one village, Nong Ya Khao, along the border with Cambodia, to see how TMAC’s operational methodology works in practice.

A long history of contamination

The village is on the site of a former refugee camp which housed Khmers from Cambodia escaping both the Vietnamese invasion and Khmer Rouge.

Resistance groups and the Thai Army used landmines to protect the area, adding to the lethal mixture of the nearby K-5 border mine belt. Frequent incursions by Vietnamese and Cambodian troops laying mines and clashing with the resistance forces have made the location of landmines extremely difficult at best. The net result is a very contaminated mined area without identifiable boundaries, generating fear and causing mine accidents among the returning Thai population.

Prior to the Landmine Impact Survey, information on the mined areas around the village was sketchy at best. Six villagers fell victim to mines attempting to clear land for agriculture inside the former refugee camp area. The village is bounded on the east side by “Siphen Road” an asphalt road built in 1996 without mine clearance. The east side of this road is considered mined by the villagers. Engineers who constructed the road claimed that mines were encountered but believe that most of the mines were pushed into the verges by bulldozers.
Vegetation includes both hard and soft wood up to 50 centimetres in diameter with the majority of trees less than 10 centimetres in diameter and up to 10 metres in height. Impenetrable bamboo thickets of all types dot the terrain. The area contains old termite mounds — steep, hard soil, honeycombed with tunnels, averaging three to five metres in base diameter with heights of up to three metres and covered in thick vegetation. These formidable obstacles are found in densities of up to 10 per hectare. The significance of these hills is their inherent tactical value. Mines are placed to deny cover to combatants. Mines were laid amidst termite hills which subsequently grew over them.

This site was used for 16 years by approximately 40,000 refugees who left a significant amount of metal contamination, making the area virtually one big rubbish dump. Heavy shelling in the area added metal fragments impregnated with explosive traces, introducing additional difficulties for using MDDs.

The explosive threat

A broad range of known anti-personnel mines contaminate the border areas. Local mine victims are primarily lower-limb amputees, suggesting a preponderance of pressure-activated anti-personnel blast mines. Villagers have identified Type 72 blast mines and Type 69 bounding fragmentation mines from identification charts they were shown. Mines laid and cleared by the Royal Thai Army included M14 and M16 anti-personnel mines and, to the west of the refugee camp along a former anti-tank ditch, M15 anti-tank mines. These mines were all expected to be encountered.

In addition, since Vietnamese and Cambodian forces in the area employed a full arsenal of conventional weapons during combat, small arms munitions, grenades, rockets, mortars and artillery munitions of all calibres were also expected.

Available information suggested a significant anti-tank mine threat on the periphery of the suspect area, with anti-personnel mines and large UXO within the affected mined areas.

Operational methodology

TMAC determined a need to address area and risk reduction actions through an integrated approach using manual deminers, MDDs and mechanical assistance in combined team efforts. Incremental introduction of trained teams and resources took several months to complete, allowing valuable experience for the teams in both the terrain and threat environments.

Manual teams were trained for clearance operations in dense jungle conditions using standard manual clearance equipment and methods. The teams were withdrawn from operations and integrated with MDD teams to operate under similar conditions.

Hampered by the thick vegetation and the severe nature of the metal contamination, operations were grudgingly slow. MDD teams required continuous retraining to operate in the highly contaminated areas which confused both the dogs and handlers. Eventually, mechanical assistance was introduced, enhancing performance dramatically by removing vegetation, metal fragments and preparing the ground for MDD teams and manual deminers.

Demining by “rai” blocks

Land measurement in Thailand is based on an ancient system. The “rai” is a standard
measurement for land, measuring 40 by 40 metres, a total of 1,600 square metres. The rai represents the amount of land needed for a family to build a house and garden to sustain a living; additional land is needed to produce surplus or cash crops.

Each farmer living in Nong Ya Khao village is allotted a 14-rai plot to cultivate crops supporting their families. This block of land measures 80 by 280 metres (or 22,400 square metres) a convenient size dividing the suspect area into manageable parcels. Unfortunately, these blocks of land were allocated in a mined area where a number of villagers lost their legs. Based on the village system of 14-rai blocks an operational plan was developed to clear priority blocks in an orderly process.

**Manual effort**

Initially, manual deminers were deployed to develop basic skills and create team cohesion. Using the asphalt road as a safe baseline, clearance lanes were laid out 25 metres apart along the road penetrating into the heavily vegetated mined area. With thick vegetation pressing on to the road verges and heavy concentrations of metal scrap mixed with mines, progress was slow.

Employing one-man drills using standard hand vegetation cutting tools, probing and excavation tools and a metal detector, proved adequate for basic operations. Heavy vegetation and high metal contamination in the suspected mined area reduced manual demining progress considerably.

Manual vegetation clearance per square metre averaged between five and 10 minutes of effort. Sweeping and surface identification using metal detectors took a similar amount of time. Metal detectors were locating metal fragments up to 15 centimetres in depth owing to the high ferrous content of the soil. Individual metal hits ranged from four to 10 hits per square metre. Averaging five hits per square metre made manual clearance and excavation work very laborious and time consuming.

Probing and excavation of targets down to a maximum depth of approximately 15 centimetres in dry season conditions with hard-baked soil is back-breaking work. Excavations as a response to signals from the metal detector take up to and beyond 30 minutes for each target to be located and removed. Locating mines or UXO under these conditions negatively affected progress.

For example, a single 30-man platoon employing 12 working lanes for eight hours a day was able to produce a maximum of 120 cleared square metres a day, although average progress was normally only 80 square metres. Over a 20-working-day period (one month’s operations) 1,600 square metres were cleared.

**Manual demining with MDD teams in support**

Following the training and integration of MDD teams to support the manual deminers the production of cleared areas increased. The full use of MDD teams is not possible in heavy vegetation. Manually cleared lanes were therefore used as a baseline to remove vegetation in the adjacent lanes allowing the deployment of MDD teams. MDDs indications were followed up by manual deminers operating from the flank of the cleared lanes.

The use of MDD teams negated the requirement to investigate every metal indication in the lanes. This dramatically reduced the areas to be swept and excavated manually.
MDD teams increased productivity by reducing the number of metal fragments to investigate. However, MDD teams are not productive while waiting for manual deminers to clear vegetation with hand-held cutting tools.

MDD teams still indicated a high number of shell and mortar fragments in the suspect area. Additional training was required to condition animal behaviour where heavy concentrations of metal fragments were mixed with mines. MDD teams can be conditioned to react to mines while passing over metal fragments, although dog interest in metal fragments could not be totally eradicated. Locating metal fragments that indicate high concentrations of explosive residue is a positive MDD team reaction but is not ideal for productivity.

During this operation, three MDD teams (each with two dogs, two handlers and one supervisor) were deployed to support half a platoon (18 people, including 12 deminers) or 12 working lanes. Productivity after MDD team corrective training cleared 300 square metres a day. Over a 20-day cycle, clearance of 3,000 square metres was typically achieved. Clearance results are best when MDD teams identify explosive-trace metal fragmentation no more than once every three to five metres.

This operation therefore doubled production using half the number of deminers.

*Mechanical area reduction*

The mechanical system employed in these operations was again based on the Pearson Survivable Demining Tractor and Tools (SDTT). Introduction of mechanical assistance to area reduction changed the deployment capabilities of both manual and MDD teams. Full use of the SDTT system allowed complete coverage of the block area in a series of mechanical applications identifying the presence or absence of mines and preparing the terrain for further investigation.

After repeated trials to maximise area reduction capacity, a simple system was developed to provide maximum assurance that all the ground had been covered. It combined mine clearance (the physical destruction of the mines as opposed to their detection) and area reduction operations.

The SDTT tractor chassis, with seven tool attachments, began by making a series of 16 passes to ensure that any landmines present were initiated or identified. The attachments included a tree extractor, a vegetation slasher, a vegetation mower, a light and heavy cultivator, a grabber, a segmented roller and a tow-behind magnet. The process of applying these tools is described in detail below.

Difficult terrain conditions with heavy vegetation cover, high-metal-content contamination and hard ground matched with the SDTT system capacity, resulted in a process where 20 working days of operations by the combined team produced the first area-reduced block. In reality, machines do not work a full eight-hour day, rather three to four hours each day.

During the dry season, five to 10 working days were needed for the mechanical operation due to vegetation thickness and soil hardness. A further 10 days are necessary for the MDD teams and manual deminers to follow up with 100 per cent coverage of the block area, when evidence of mines or UXO was confirmed by the machines.
If a block area had no evidence of mines then the block was 10 per cent checked by MDD teams and manual deminers using standard clearance methods. This took only two or three days. During a 10 per cent check, areas are selected where machines or attachments did not perform well or other areas where mines are likely to be found.

Once the process started, moving in sequence an average of 20 working days was required to area-reduce one block. The workforce for these operations was considerably smaller, totalling 23 personnel as follows:

Table 2.

<table>
<thead>
<tr>
<th>Integrated mechanical/mine dog/manual team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team commander</td>
</tr>
<tr>
<td>Team deputy</td>
</tr>
<tr>
<td>Mechanical assistance section:</td>
</tr>
<tr>
<td>Mechanical unit commander</td>
</tr>
<tr>
<td>2 SDTT x 2</td>
</tr>
<tr>
<td>2 SDTT operators</td>
</tr>
<tr>
<td>MDD section:</td>
</tr>
<tr>
<td>4 MDD teams</td>
</tr>
<tr>
<td>2 MDD supervisors</td>
</tr>
<tr>
<td>8 mine dogs</td>
</tr>
<tr>
<td>8 dog handlers</td>
</tr>
<tr>
<td>Manual demining team</td>
</tr>
<tr>
<td>Supervisor</td>
</tr>
<tr>
<td>6 deminers</td>
</tr>
<tr>
<td>Medical</td>
</tr>
<tr>
<td>One medic</td>
</tr>
<tr>
<td><strong>Total: 23 people</strong></td>
</tr>
</tbody>
</table>

The emphasis of this operation was “horsepower” over “manpower”, capitalising on the advantage of mechanised systems for removing obstacles and preparing the way for MDD teams and manual deminers.

**Summary of performance**

*Manual mine clearance operations and operations supported by MDD teams*

Manual demining was conducted at a base rate of 1,600 square metres in a 20-day period or a slow clearance rate of 80 square metres per day in very high metal contamination and heavy vegetation conditions. These operations are clearance tasks, which only manual deminers can perform due to inherent limited technical performance of metal detectors and hand-tools used to locate mines or UXO.

Adding MDD teams to the procedure increases performance. However the process is still basic clearance operations. Area reduction is enhanced by the mine dog capability to focus on explosive vapours instead of non-hazardous metal scrap as located by metal detectors.

MDD teams supporting manual clearance where deminers remove vegetation manually allows limited deployment of the MDD team. However, clearance capacity increased to 3,000 square metres per 20-day period. This represents an 87.5 per cent increase in productivity over standard manual methods.
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**Area reduction with mechanical assistance followed by mine clearance operations**

During 20-day periods the SDTT system was deployed to remove vegetation, break up ground to activate landmines and conduct multi-level investigation. These activities prepare terrain for MDD and manual deminer team deployment to maximum effectiveness, reducing threat and encumbrance from tripwires, vegetation, metal contamination and hard soil.

Mechanical assistance supporting MDD and manual demining teams can reduce as much as 22,400 square metres in 20 days, equalling a 1,400 per cent increase over manual or a 746.6 per cent increase over MDD teams with manual deminers in support. In addition, another 22,400 square metre area was mechanically reduced during the same period, although a MDD team was not available to complete the 10 per cent check during the same timeframe.

This totalled a 2,100 per cent increase in productivity over manual methods or a 1,120 per cent increase over MDD with manual deminer teams. These results are summarised in Figure 10 below.

**Fig. 10. The increasing productivity of integrated area reduction operations**

**Methods of area reduction (dry and wet season)**

**Dry season operations**

**Step 1. Establish area boundaries**

Arbitrary boundaries defining the area where operations will be conducted are based on the capability of the mechanical system and the terrain features. The SDTT mounted on steel wheels is driven into the area outlining the perimeter and marking the four corners with flags to guide operations. The SDTT is equipped with the heavy slasher mounted on the front and grabber mounted on the rear of the tractor chassis.
The commander directs the operator by radio on a bearing and distance using the heavy slasher to cut lanes forming a block. Yellow flags are erected at each corner of the inner box visually identifying the boundaries to both the operator and commander. The lane established by the first pass of the SDTT around the box is now considered a turn-around area and overlap zone for subsequent blocks. During these operations the 14-rai block (80 x 280 metres) is used, corresponding with the needs of the beneficiaries and the technical capabilities of the systems and operators.

**Step 2. Remove heavy vegetation (one pass)**

The SDTT is now directed by the commander in a series of passes to cut down all heavy vegetation of up to 10 centimetres in diameter within the block area. Both the operator and commander observe the progress of the operations.
**Grabber (one pass):** The heavy slasher leaves a considerable amount of debris in its wake. Broken vegetation stems litter the area and are picked up in batches by the grabber. Piles of debris are established outside the suspect area in safe areas. Mounted on the tractor is the light or heavy tree extractor which can be used to pull trees out of the ground and remove them from the area as necessary. Normally, trees over 10 centimetres in diameter are left in place, as mines are not likely to have been laid underneath them.

*Fig. 15. Combined usage of the grabber and tree pullers to remove the debris and place batches into safe areas for deminers to check.*

**Light Vegetation Removal (one pass):** The SDTT is now mounted with the push/pull mower. The purpose of the mower is to reduce remaining vegetation stubble and debris to ground level. Cutting down the stubble allows the effective deployment of the roller and magnet. The mower is deployed in an overlapping pattern ensuring consistent cutting of remaining vegetation.

*Fig. 16. Mowing the stubble allows the effective deployment of the articulating roller and magnet.*
Step 3. Investigate the threat and remove surface metal with a magnet (one pass)

The heavy magnet is mounted on the rear of the SDTT and pulled in overlapping sweeps along the length of the block. In the turnaround areas at the end of the block, the magnet plate is released dropping collected metal fragments onto a tarpaulin. Deminers are employed to observe, identify and dispose of hazardous material, which also identifies further potential threats in the lane and other areas of the block.

Fig. 17. Passing the magnet in overlapping sweeps and checking the results at the end of each lane is an efficient method to remove metal and identify threats in the block or lane.

Step 4. Investigate the threat with segmented roller (four passes)

The segmented articulating roller is mounted on the front of the vehicle. Systematic rolling in overlapping passes at 50 per cent of roller width is conducted over the full area of the block. Three additional passes are made over the area until all four cardinal directions are completed by rolling vertically, horizontally and both diagonals. Theoretically, each area of ground will be impacted by the mechanical pressure from a 50 kilogram roller up to eight times.

Fig. 18. Complete coverage of the block is achieved by overlapping passes.
Step 5. Investigate the threat at depth with light cultivator (one pass)

Light cultivator is adjusted to 10 centimetre digging depth and mounted on the rear of the SDTT. The light cultivator is pulled in overlapping sweeps over the entire block. This action disrupts hard soil creating access for additional applications of the magnet and roller at greater depths.

Fig. 19. Light cultivator is the first step in sub-surface investigation for evidence of mines.

Step 6. Investigate the threat at depth with magnet (one pass)

In line with cultivated furrows the heavy magnet is pulled in overlapping sweeps along the length of the block, picking up sub-surface exposed metal or mines and components.

Fig. 20. The magnet is pulled in the same direction as cultivated furrows.

Step 7. Conduct deeper threat investigation with heavy cultivator (one pass)

The heavy cultivator is adjusted to 20 centimetre digging depth and pulled over the block area in a different direction to the light cultivator. Again, overlapping passes are used to ensure total coverage. The direction is determined by terrain features on the ground.

Fig. 21. The heavy cultivator is pulled in a different direction to the light cultivator.
**Step 8. Conduct deeper threat investigation with magnet (one pass)**

The heavy magnet is mounted on the rear of the SDTT again and pulled in overlapping sweeps along the full length of the block.

*Fig. 22. The magnet follows the same pattern as the heavy cultivator collecting metal fragments or mines.*

**Step 9. Conduct deeper threat investigation with segmented roller (four passes)**

Four additional passes are made over the area until all four cardinal directions are completed, attempting to detonate mines that may have been brought to the surface by the light and heavy cultivator.

*Fig. 23. Final passage of the roller is intended to ensure no further evidence of threat is present.*

**Total passes – 16:** This repetitive system starting at the surface and processing the ground to find evidence of mines is an area reduction process and is not considered mine clearance by TMAC. After conducting this process without finding evidence of mines, the reduced area is then released.

**Wet season operations**

Increased moisture content in the soil reduces the effectiveness and mobility of mechanical systems. The process must therefore be modified during the wet season. The same activities are conducted with fewer passes based on how the soil responds to the machine and its attachments. The passes used are as follows:

- establish area boundaries,
- heavy vegetation removal (one pass),
- grabber (one pass),
- light vegetation removal (one pass),
- magnet (one pass),
articulating roller (four passes).

**Total Passes: 8.**

Depending on the soil moisture and how the soil reacts to the machine and its attachments, additional passes are attempted increasingly until the full 16 passes can be implemented without turning the field into a morass.

**Action taken on evidence of hazardous threat**

Carefully controlling all activities through visual observation and gathering information is obtained by the following three methods:

- visual identification of mines/UXO,
- detonation of mines/UXO through activation by roller or cultivator, or
- magnetic collection of mines/UXO or components.

**Visual identification**

Equipment operators, commanders and deminers can observe the presence of exposed mines or components throughout the process. Once a suspected mine is identified it will be located through triangulation and recorded for further clearance action.

**Detonation of mines/UXO through mechanical activation**

Multiple passes of the mechanical equipment and tools provide the opportunity for mines to detonate as designed. Observing detonations and recording the location through triangulation identifies primary threat areas for clearance action.

**Fig. 24. Mine strike using mechanical equipment immediately identifies the threat area.**

If a detonation is consistent with a landmine the entire box is considered mined. Depending on the nature of the detonation (for example an explosion consistent with an anti-personnel mine) mechanical operations may continue in the block, further identifying other areas or reducing risk and ultimately preparing the terrain for manual and MDD teams.

**Magnetic collection**

Passing the magnet over the ground after vegetation clearance offers the opportunity to collect surface-laid or exposed mines and their components. Magnet strength does not allow mines to be “sucked” out of the ground although considerable metal debris can be collected. The debris tell a story, showing contamination levels and types of munitions expected.

The magnet’s removal of metal fragmentation increases the effectiveness of manual deminers, and removal of explosive-encrusted metal amplifies the efficiency of MDD
teams. Positive identification of hazardous material narrows the search to the lane where the hazard was picked up.

**No evidence of mines or other hazard**

If, after repeated passes of the SDTT tractor and mechanical application of a full range of attachments no evidence of mines is produced or witnessed, the assumption is that mines are unlikely to be present. Knowing that no system is infallible, confirmatory checks are necessary.

Checking areas where mechanical application is weak or ineffective (such as steep slopes) is therefore obligatory. Areas where mines are known to be frequently located (e.g. around water sources and field fortifications) are also checked using alternative methods. Following up with MDD teams and manual deminers ensures the mechanical process is reinforced. Using dogs and metal detectors brings two separate sensory methods of checking or quality assurance to the mechanical area and risk reduction process.

**Confirmatory checks with alternate sensory method**

Follow up of systematic mechanical area and risk reduction operations should employ a different methodology than the primary methods employed. MDD and manual teams are ideal to confirm the effectiveness of mechanical systems.

**Fig. 25. Following thorough mechanical application, MDD teams and manual deminers perform quality assurance checks and investigate areas where mechanical systems perform poorly.**

Once the mechanical system has moved to another block, MDD and manual teams can check the block. Arbitrarily, 10 per cent of the block is the recommended level of checking until quantifiable tests can be conducted on the mechanical system. Should the teams find any evidence of mines the entire block must be cleared by both MDD and manual teams, or just manually. However, if no mines are found during this confirmatory check then the area is declared released.

**Evidence of mines**

At any stage in the TMAC process the first indication of mines initiates a “100 per cent clearance of area” response. The block becomes the arbitrary area where the full measure of MDD and manual clearance effort will be deployed in standard clearance operations.
Systematic area reduction operations

These procedures are repeated over the entire suspected mined area, block by block, until all mined areas are identified or shown to contain no evidence of mines. Understanding the difference between blocks that are “reduced” and blocks that are “mine cleared” is important. Considerable time was invested educating farmers and other beneficiaries receiving the cleared or area reduced land. The local perspective is quite practical in that, following the repeated processes of the mechanical equipment, farmers are satisfied to take over the land.

Additional checks with MDD and manual teams provide marginal increases in farmer confidence after witnessing the effects of mechanical methods that produce no mine evidence. Greatest confidence is achieved when MDD and manual teams deploy to fully clear areas identified containing mines.

During these operations two types of mines were located: Chinese Type 72A pressure-activated anti-personnel mine and the Chinese Type 69 bounding fragmentation mine. Type 69 mines were found by visual observation, magnet and MDD teams with manual deminers. In all cases these mines were missing the plastic fuse, which had deteriorated as a result of the forces of nature, and the tripwires had long since disappeared.

During clearance operations, in the vicinity of the Type 69 mines, additional Type 72A mines were located by MDD teams and uncovered by manual deminers. The mines appeared to be in generally good condition although weathered with possible water intrusion into the mechanism and firing chain. No mines were detonated during area reduction operations, indicating either the depth of the mines did not allow them to detonate as intended or their firing mechanisms had deteriorated.

Quality control process

Defining adequate quality control (QC) procedures to follow up repetitive mechanical processes with a 10 per cent MDD and manual check requires either new technologies or a sensor system that adds value to the described area reduction methodology.

However, during these operations in Thailand a final QC process was implemented, witnessed and directed by third party stakeholders, e.g. members of non-governmental organisations and military engineering technical staff. The roller system was directed at random by QC participants in blocks. Also, MDD and manual teams were directed to conduct random checks of areas until the QC monitors were satisfied with the results. During these random checks and QC operations, no mines were either detonated or discovered.
Conclusions, findings and recommendations

Conclusion 1.

In patterned mined areas machines are used to identify the exact presence of mines. In non-patterned mined areas machines are used to identify the areas containing mines. The potential for machines to reduce the amount of land deemed contaminated with mines and UXO is significant.

Findings

In a patterned mined area, demining organisations work with available information, which is often comprehensive. Mines are generally found in a deliberate formation. A machine can identify patterned minefield perimeters so that clearance assets can deploy to the affected area quickly.

In patterned minefields, information is often extensive but its reliability may require confirmation. Machines can be used to effectively verify this. If the information proves reliable, it may impact on future clearance techniques used in the area. If the information proves unreliable then greater caution is required in its use.

In non-patterned mined areas, a process to obtain greater information is required. Typically, available information is vague. A machine process is a good way to provide information to a level that suspect areas can be cancelled out. Various threat possibilities can be categorised, with each being targeted successively. For example, the presence of metal-cased mines, UXO and metal mine components can be identified by the use of a magnet whereas pressure-activated plastic anti-personnel mines might be identified with the use of a roller. Other technologies could assist with other mine threats. The basic requirement would be to identify the likely threat types using the most appropriate technology to identify a presence.

In non-patterned mined areas, land can be divided into workable sections. The size of each section might depend on the mine history of the area as well as terrain. Sectioning allows for areas to be separated into two categories; those which have been shown to contain a mine threat, and those which have not.

Recommendation 1.

Demining organisations need to invest in technology that will deliver more information about a minefield prior to clearance operations. This information can save both time and money and, as a result, more minefields can be cleared in a given time. Machines can apply a series of confirmation tools including those designed to detonate mines, electronically indicate and map the location of mines and UXO, pick up or retrieve metal-cased mines and UXO, and collect explosive vapour.

Conclusion 2.

Technical survey involving area reduction with machines has the potential to rapidly release large suspected hazardous areas.

Findings

Applying the world’s limited mine clearance resources to actually clearing all suspected land, rather than identifying areas that do not contain mines is wasteful. Changing focus to “area reduction operations” followed up by “mine clearance operations” of identified threats will have a greater and quicker impact on the mine and UXO threat.
Eliminating suspected hazardous areas where no evidence of a threat is found through a systematic mechanical area reduction process has clear advantages. This process allows mine clearance resources to be deployed where real threats are located, as opposed to huge suspect areas subsequently shown not to contain mines.

Areas deemed as requiring clearance are typically identified in a general mine action assessment. Information is gained via a variety of means — e.g. verbal interaction or mined area documentation such as sketch maps. Information gained in the general assessment should be proven and confirmed by physically “doing something”, i.e. conduct a technical survey. The use of machines to provide on-the-ground confirmation in technical survey is not a standard approach among most demining organisations.

If most of the work in demining is searching for mines rather than clearing them, more effort is required during the technical survey phase of an operation. Immediately switching to clearance operations after the conduct of a verbally based technical survey is arguably not the best use of clearance resources.

In both case studies in this chapter, productivity results show that investment in an area reduction machine results in a high return when compared to the other technical survey or clearance methods used (MDD and manual). Moreover, there are probably more efficient methods of conducting full clearance than those used in the case studies and therefore the results are only an indication of potential productivity increases. In any case, using a method that more accurately locates mines and thereby reduces the size of the area to be cleared will almost always produce a positive cost-effective result.

**Recommendation 2.**

*Machines can be effective tools to hasten the technical survey process, quickly revealing the true areas containing mines and requiring full clearance. The use of mechanical systems during technical survey should be standard where physical conditions allow.*

**Conclusion 3.**

*The effect of mechanical action upon mines is not 100 per cent predictable. Machines vary in their ability to destroy ordnance and the physical conditions in which they work will have a bearing on the outcome. However, machines are effective enough that they can be expected to at least indicate the presence of mines and can therefore be used for area reduction. This is borne out by tests and empirical clearance data.*

**Findings**

The reliability of the machine tool is more of a general concern, as reliability will differ from machine to machine, and will depend on how each machine is applied and the mine type it is up against. In addition, a machine’s reliability should be compared to the ability of other methods to do the same job (e.g. REST and MDD techniques or manual survey lanes). Despite certain grey areas as to a machine’s effectiveness against ordnance, consideration should be given to how much slower area reduction will be if means other than mechanical must be relied upon.

**Recommendation 3.**

*Since an objective comparison between clearance methods is unlikely to be available in the short term, demining organisations should be encouraged to exchange machine*
reliability data and knowledge while continuing to work with the degree of confidence each has in the respective methods deployed.
Endnotes

1. A risk assessment is a key ingredient in a mechanical area reduction operation. It involves a closer look at the information obtained about a minefield with the aim of cancelling out areas requiring clearance in an informed and transparent way.
3. In other trials HALO has conducted, the roller has proved less effective against PMA-2 anti-personnel mines (50-60 per cent success rate) as the fuses tend to be broken off from the initial side-forces of the roller effect. Also the PMD-6 mine is not easily initiated (40-50 per cent effective) as the wooden construction of the mine crumbles at the joints thereby not applying sufficient downward force on the fuse.
4. The HALO Trust (1999b) and (2000a).
5. The platoon configuration was one commander, one second-in-command, three section commanders, 24 deminers and one medic.
6. MDD teams only work four hours a day due to temperatures and the ability of manual deminers to clear enough vegetation allowing the MDD teams to deploy.
8. Neither the manual nor the MDD procedures were fully optimised. For example, machines were not used to prepare the ground for manual clearance or MDDs to increase their productivity. Clearance performance is therefore an extreme comparison and only indicative of the options used.
9. Since this case study was written the dry season procedure has been refined and the total number of passes has been reduced.